Claims

[c1] 1.A system for controlling braking of a vehicle, comprising:

regenerative brakes connected to wheels of a first axle of said vehicle;

non-regenerative brakes connected to wheels of a second axle of said vehicle different from said first axle;

a plurality of sensors for measuring and providing electronic signals to monitor vehicle inputs;

a controller adapted to continuously receive and process said signals; and

a generator motor activated by said controller for adjustably applying regenerative braking torque independently to each wheel of said first axle for maintaining a vehicle controllability value within a preselected target range.

[c2] 2.The system of claim 1, wherein the plurality of sensors comprise a brake pedal position, wheel speed of each wheel of said vehicle, and degree of steering angle deviation right or left of a straight ahead direction of travel by said vehicle.

[c3] 3.The system of claim 1, wherein the controller is a simple proportional-integral-derivative feedback controller.

[c4] 4.The system of claim 2, wherein:

the wheels on a front axle are steerable;

the generator motor provides regenerative braking torque to the wheels on a rear axle;

the plurality of sensors further comprises lateral acceleration and yaw rate; and

the controller's ability to proportionally increase non-regenerative braking of one-wheel comprises increases to the non-regenerative brake of a wheel on an outside of a turn traveled by said vehicle.

[c5] 5.The system of claim 2, wherein:

the wheels on a front axle are steerable;

the generator motor provides regenerative braking torque to the wheels on the front axle;

non-regenerative brakes are connected to the wheels on a rear axle; sensor input to said controller further comprises lateral acceleration and yaw rate; and

the controller proportionally increases the non-regenerative brakes a wheel on an inside of a turn traveled by said vehicle.

[c6] 6.The system of claim 1, wherein vehicle controllability is optimized using a determination of a longitudinal wheel slip ratio value.

[c7] 7.The system of claim 1, wherein vehicle controllability is optimized using a determination of a target tire slip angle and an actual measured tire slip angle.

[c8] 8.The system of claim 1, wherein vehicle controllability is optimized using a determination of target yaw rate and actual measured yaw rate.

[c9] 9.The system of claim 2, wherein the steering angle to the left or right is determined from a detection of steering wheel position.

[c10] 10.The system of claim 2, wherein the steering angle is determined from a detection of the steerable wheel position.

[c11] 11.The system of claim 2, wherein the steering angle is derived from a time-filtered determination of steering angle.

[c12] 12.The system of claim 6, wherein the controller reduces regenerative braking and proportionally increases non-regenerative braking to maintain vehicle controllability when the longitudinal wheel slip ratio value is greater than 10 percent.

[c13] 13.The system of claim 6, wherein the controller reduces regenerative braking and proportionally increases non-regenerative braking to maintain vehicle controllability when the longitudinal wheel slip ratio value is greater than 5 percent.

[c14] 14.The system of claim 6, wherein the controller reduces regenerative braking and proportionally increases non-regenerative braking to maintain vehicle controllability when the longitudinal wheel slip ratio value is greater than a

value that is dependent on vehicle operating conditions.

[c15] 15.A method to control braking and optimize controllability of a vehicle having a generator motor adapted to adjustably apply regenerative braking torque independently to wheels of a first axle and non-regenerative brakes connected to wheels of a second axle, comprising the steps of:

controlling the vehicle by sensing vehicle conditions including at least one of brake position, wheel speed of each wheel, and degree of steering angle deviation right or left of a straight ahead direction;

activating non-regenerative and regenerative braking in varying proportion independently among wheels of said first and second axles;

determining vehicle controllability based on comparison of at least one measured vehicle controllability value against at least one predetermined target value; and

reducing regenerative braking while increasing the non-regenerative braking to a selected wheel to maintain the actual vehicle controllability value within the predetermined target value.

[c16] 16.The method of claim 15, wherein the step of controlling the vehicle comprises using a simple proportional-integral-derivative feedback controller.

[c17] 17.The method of claim 15, wherein:

wheels on a front axle are steerable;

the generator motor controls regenerative braking torque applied to the wheels on a rear axle;

non-regenerative brakes are connected to the wheels on the front axle;

the step of sensing vehicle conditions further comprises determining lateral acceleration and yaw rate of the vehicle; and

the step of reducing regenerative braking while increasing the non-regenerative braking to one wheel to maintain the actual vehicle controllability value within the predetermined target value comprises the step of increasing proportionally the non-regenerative brake torque applied to a wheel which travels on an outside of a turn.

[c18] 18.The method of claim 15, wherein:

the wheels on the front axle are steerable;
the generator motor adjustably controls regenerative braking torque applied to the wheels on a front axle;
non-regenerative brakes are connected to the wheels on a rear axle;
the step of sensing vehicle conditions further comprises the step of determining lateral acceleration and yaw rate of the vehicle; and
the step of reducing regenerative braking while increasing the non-regenerative braking to one wheel to maintain the actual vehicle controllability value within a predetermined target value comprises the step of increasing proportionally the non-regenerative braking torque applied to a wheel traveling on an inside of a turn.

[c19] 19.The method of claim 15, wherein the vehicle controllability determination includes the step of measurement a longitudinal wheel slip ratio value.

[c20] 20.The method of claim 15, wherein the vehicle controllability determination includes the step of determining and comparing a target and actual vehicle tire slip angle.

[c21] 21.The method of claim 15, wherein the vehicle controllability determination includes the step of determining and comparing target and actual yaw rate.

[c22] 22.The method of claim 19, wherein the step of reducing regenerative braking is activated when the longitudinal wheel slip ratio value is greater than 10 percent.

[c23] 23.The method of claim 19, wherein the step of reducing regenerative braking is activated when the longitudinal wheel slip ratio value is greater than 5 percent.

[c24] 24.The method of claim 19, wherein the step of reducing regenerative braking is activated when the longitudinal wheel slip ratio value is greater than a value that is dependent on vehicle operating conditions.

[c25] 25.Apparatus for continuously controlling braking and optimizing controllability of a vehicle, comprising:

a generator motor for providing regenerative braking torque to the wheels a first axle;

non-regenerative brakes being connected to the wheels of a second axle;

a controller adapted to operate said generator motor;

regenerative braking and non-regenerative braking being independently adjustably applied to wheels of said first and second axles; and

a control system embodied in the controller for directing the controller to sense vehicle conditions including brake position, wheel speed of each wheel, and degree of steering angle deviation right or left of a straight ahead orientation,

said control system being adapted to activate non-regenerative and regenerative braking in varying proportion independently among the wheels of said first axle and said second axle, and to determine vehicle controllability based on at least one measured vehicle controllability value and at least one predetermined target value, and, based on such determination, and to

reduce regenerative braking while increasing the non-regenerative braking to one wheel to maintain the actual vehicle controllability value within the predetermined target value.

[c26]

26.An automotive vehicle, comprising:

a generator motor for adjustably independently applying regenerative braking torque to the wheels on at least one axle;

non-regenerative brakes connected to the wheels of at least one axle;

a controller;

the regenerative and non-regenerative braking being applied to wheels of different axles; and

a control system embodied in the controller for directing the controller to sense vehicle conditions including one or more of brake position, wheel speed of each wheel, and degree of steering angle deviation right or left of a straight ahead orientation, activate non-regenerative and regenerative braking in varying proportion between wheels of a front axle and wheels of a rear axle, determine vehicle controllability based on at

least one actual vehicle controllability value and at least one predetermined target value, and

reduce regenerative braking while increasing the non-regenerative braking to one wheel to maintain the actual vehicle controllability value within the predetermined target value.